



Glenn Research Center

Technology Insertion

2 Technology Assessment / System Studies

Denise S. Ponchak



Glenn Research Center

Technology Assessment / System Studies

Center: GRC
Funding Enterprise: Code M/SOMO
UPN-5: 315-90, 632-50

POC: D. Ponchak
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Date: 3/25/1999
NTIDB Record #: 9448, 1886
Tech Prog Element #: 2
Planned TRL: 1

DESCRIPTION:

- The objective of this effort is to develop application strategies to incorporate new communications technologies into NASA missions to accomplish Agency goals, and stimulate the development of communications technology.
- This is accomplished through studies that: validate, revise or expand relevant technology forecasts; and perform system analysis for emerging NASA missions, including performance, mass, power, technology & cost/benefit trades.

JUSTIFICATION:

- Awareness of advanced communications research through-out the world and having the ability to forecast technology is essential to focus our limited science and technology resources to maximize the Nation's Return On Investment.
- Studies support determining the extent of NASA's ability to transition to commercial communications systems.
- Communications systems analysis is fundamental, necessary pre-phase A activity for all missions and projects.
- Focussed studies will ensure an efficient implementation of the Space Internet by identifying and prioritizing future technology development efforts.

RESOURCES (\$K):

	FY98	FY99	FY00	FY01	FY02	FY03
Guideline	240	350	375	370	610	610

MILESTONES:

- Q1FY99 - Complete Technology Assessment of MEMS Telecommunications Applications. SAIC Contract, Dr. Giles Crimi.
- Q2FY99 - Begin Space Internet Comm and Networks Technology Assessment Study. Co-funded with CETDP.
- Q3FY99 - Complete ISS Commercial Communications Enhancement Study.
- Q4FY99 - Complete Communications Technology Trade Studies to support Mars Infrastructure Study.
- Q3FY00 - Complete Space Internet Communications and Networks Technology Assessment. Publish Volume V.



Technology Assessment / System Studies

STATUS:

- Phased Arrays, TWTAs, and Protocol efforts for Mars Infrastructure Study underway. SCP providing MarSat proposal evaluators.
- ISS Commercial Communications Enhancement Study completing in April, 1999 with briefing to F. Buzzard / ISS.
- Space Internet Comm and Networks Technology Assessment Study awaiting fund authority from CETDP.

CUSTOMER(S):

- NASA Johnson Space Center - SOMO - supports technology investment planning of SOCTP.
- NASA Code S CETDP - Supports technology investment planning of HRDD.
- ES, SS, and HEDS - Supports advanced mission planning.

MISSION RELEVANCE:

- This effort is broad in scope and supports the future direction of HEDS, ES, and SS Enterprises.
- The studies provide information concerning emerging technologies and new communications applications that can benefit NASA Space Missions.

MAPPING TO STRATEGIC ROADMAP:

Pillar 1: Reduce Cost of	1. Commercial Utilization	<input checked="" type="checkbox"/>	Pillar 2: Provide enabling	1. High Performance Comm	<input checked="" type="checkbox"/>
NASA Space Operations	2. Network Interoperability	<input checked="" type="checkbox"/>	data services to Enterprises	2. Intelligent Syst & Autonomy	<input type="checkbox"/>
	3. System Automation	<input type="checkbox"/>		3. Innovative Info Syst	<input type="checkbox"/>
	4. Process Tools	<input type="checkbox"/>		4. Environm Characterization	<input type="checkbox"/>

INTER-RELATIONSHIPS:

- Presently there is a proposal for joint funding with CETDP for the Space Internet Technology Investigations.

IMPACT OF CANCELLATION or DELAY :

- Both delay and cancellation can have a large negative effect. Without the information basis these studies provide for making sound programmatic decisions, the rationale for technology investments becomes very vulnerable. Given the current resource constraints, bad decisions due to incomplete or inadequate knowledge can lead to large program budget and/or schedule overruns.



Technology Assessment / System Studies

Technology Directions for the 21st Century

Volume I

May 1996

Moore's law and Semiconductor Technology Trends
Computing Technology Trends
Storage technology Trends
Photonics Technology Trends

Volume II

May 1996

Database Technology Trends
Software Technology Trends
Neural and Fuzzy Technology Trends
Artificial Intelligence Technology Trends

Volume III

September 1996

Terrestrial Telecommunications Services
Technology Trends
Mobile Satellite Service Technology Trends

Volume IV

May 1998

Data Compression Technology Trends
Low Power Electronics Technology Trends
Trends in Nanotechnology
Broadband Communications Satellite Services

Volume V

October 1999

Microelectromechanical Systems (MEMS) for
Space
Satellite Communications at V- and W-Band
Communications and Networks Enabling
Technology for the IOA

A sound basis for government technology investments is essential.



Commercial Communication Future Capabilities Assessment

- Completed initial communication company interviews and identified current commercial satellite network capabilities
 - Orblink (5/29), Teledesic (7/21), Boeing 8/13), Hughes (8/25)
 - New systems have been recently proposed
 - Teledesic (KUBS), Hughes (Spacelink), & Lockheed Martin (Astrolink)
- Identified need for NASA traffic model to accurately forecast future commercial capabilities
 - Data rates / peak demand requirements / latency requirements
 - Magnitude of NASA's future communication's needs
 - ISS update in April '99, final model expected in June '99



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Technology Insertion

3 Direct Data Distribution (D^3)

Lawrence W. Wald



Glenn Research Center

Direct Data Distribution (D³)

Center: GRC
Funding Enterprise: Code M/SOMO
UPN-5: 315-90, 632-50

POC: L. Wald
Phone: 216.433.5219
email: lwald@grc.nasa.gov
Current TRL: 4

Date: 3/30/1999
NTIDB Record #: 9456, 9453, 9454, 9455
Tech Prog Element #: 3
Planned TRL: 7

DESCRIPTION:

- The D³ Project will demonstrate an advanced, high-performance communications system that transmits information at up to 1.2 Gbits per sec directly from the Space Shuttle in low-Earth orbit (LEO), using Ka band commercial frequencies, to a small (<1.8 meter) low cost tracking ground terminal on the Earth. The Shuttle-based communications package will utilize a solid-state, Ka-band phased array antenna that electronically steers the RF signal toward the ground terminal.
- D³ will demonstrate new bandwidth efficient modem technology that will allow transmission of substantially increased amounts of data collected from LEO platforms directly to NASA field centers, principal investigators, or into the commercial terrestrial communications network.

JUSTIFICATION:

- The successful demonstration of this communications link is essential to the success of future NASA missions. This capability will provide the means to manage the unprecedented amounts of data that will be generated by space-borne instruments and facilities.
- The components being used in the D³ system are being designed in concert with commercial developers who will use similar technology in future commercial space communication systems. This will help facilitate the NASA transition to commercial communication systems.

RESOURCES (\$K):

	FY98	FY99	FY00	FY01	FY02	FY03
Guideline	360	975	1910	2715	2440	850

MILESTONES:

- | | | | |
|--------|--|--|--------------------------------------|
| • FY99 | 2Q: 1628 Submittal | 3Q: JSC Phase 0/1 Flight Safety Review | 4Q: Complete the PDR |
| • FY00 | 1Q: KSC Phase 1/2 Ground Safety Review | 1Q: Raytheon Array Delivery to GRC | 4Q: Complete the CDR |
| • FY01 | 1Q: JSC Phase 2 Flight Safety Review | 1Q: KSC Phase 2 Ground Safety Review | 4Q: JSC Phase 3 Flight Safety Review |

STATUS:

- The Request for Manifest (1628) has been submitted to NASA HQ/Code M for review and approval.
- D³ is in Phase B with a combined civil service/contractor team working the design of the flight and ground segments of the experiment. Preliminary contacts have been made with JSC and GSFC Hitchhiker personnel to begin working integration and safety issues.



Direct Data Distribution (D³)

CUSTOMER(S):

- The primary customer is the HEDS Enterprise with the focal point being Charlene Gilbert/SOMO. An additional HEDS customer is Frank Buzzard, ISS Chief Engineer. HEDS technology needs include Advanced Communications and Operations and High Bandwidth Ground-Space Communication.
- Additional Enterprise customers include Earth and Space Science Enterprises. Their technology needs include High Data Rate Communication, Lightweight and Low Power Robust Electronics Systems, and Improvements in Data Collection, Transmission and Processing.

MISSION RELEVANCE:

- The flight validated D³ technology will be used for future ISS operations. A commercial array will be available in FY03 to support HEDS facilities and vehicle communications needs. The commercial high data rate modems will be available FY02.
- These technologies, deployed as part of an integrated space network and architecture, will provide the reliable and low cost solutions necessary to support ISS and HEDS requirements.

MAPPING TO STRATEGIC ROADMAP:

Pillar 1: Reduce Cost of	1. Commercial Utilization	<input checked="" type="checkbox"/>	Pillar 2: Provide enabling	1. High Performance Comm	<input checked="" type="checkbox"/>
NASA Space Operations	2. Network Interoperability	<input type="checkbox"/>	data services to Enterprises	2. Intelligent Syst & Autonomy	<input type="checkbox"/>
	3. System Automation	<input type="checkbox"/>		3. Innovative Info Syst	<input type="checkbox"/>
	4. Process Tools	<input type="checkbox"/>		4. Environm Characterization	<input type="checkbox"/>

INTER-RELATIONSHIPS:

- All technology development has been funded by CETDP. The GRC CTD has a \$ 6M 50/50 cooperative agreement with the Raytheon Systems Company to build the Ka Band Phased Array. The SICOM modem technology began as an SBIR effort and has led to the task to develop a Rad-Hard modem. The rad-hard modem is being funded by CETDP, GSFC, and SICOM. Modem development has been split roughly 50/50 between SICOM and NASA.

IMPACT OF CANCELLATION or DELAY :

- Cancellation will delay or possibly preclude the flight demonstration of key components necessary to support future NASA missions in the HEDS, Earth Science, and Space Science Enterprises. CETDP has supported the RSC Array development with the goal of a flight opportunity for the array. Raytheon Systems Company, the partner in the array development, is planning on this flight opportunity for space flight validation.



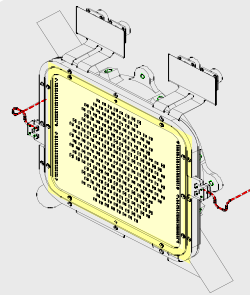
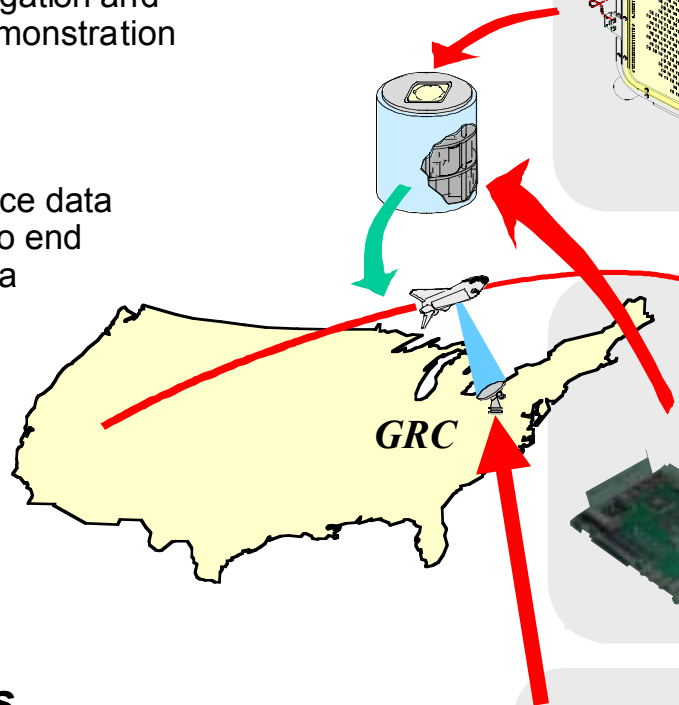
Direct Data Distribution (D³)

Approach

- Hitchhiker Experiment on Shuttle for NASA missions risk mitigation and commercial services demonstration

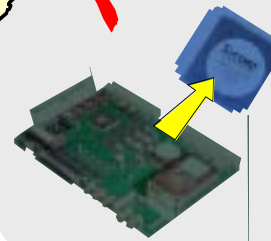
Features

- Direct distribution of space data from LEO at 622 Mbps to end user or archive facility via terrestrial networks
- Commercially owned and operated space and ground segments at commercial frequency



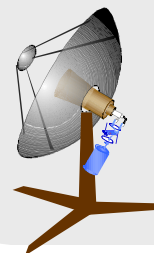
• 19 GHz MMIC Transmit Phased Array

- GRC/Raytheon Cooperative Agreement with 50/50 cost sharing



• 155 Mbps Digital Encoder-Modulator

- GRC/SICOM SBIR II & Space Act Agreement
- Building block for 622 Mbps multi-channel solution



• Cryoreceiver-Based 0.9 m Tracking Earth Terminal

- GRC integration of InP PHEMT LNA, HTS filter, and cryocooler technologies

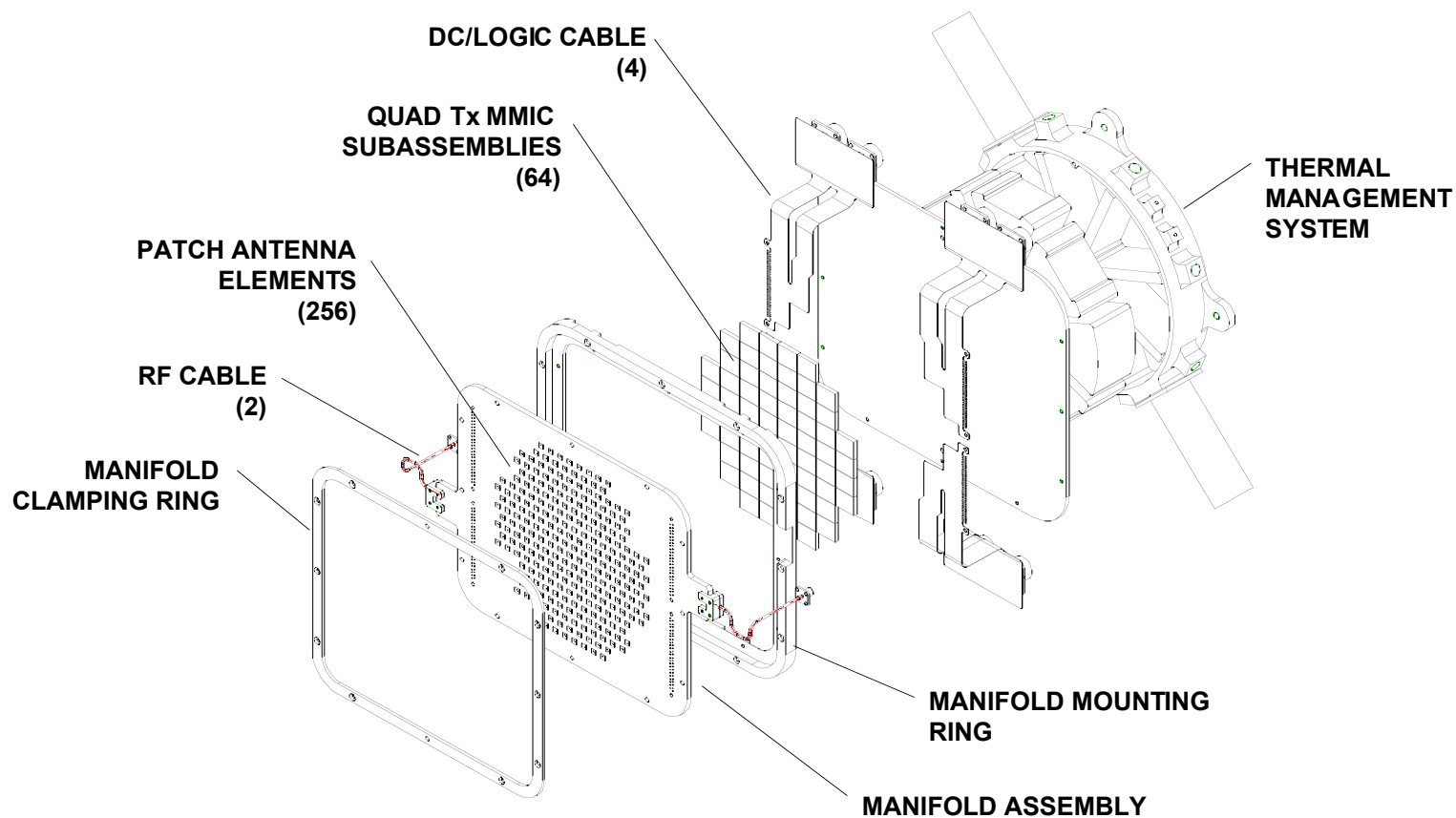
Enterprise Benefits

- Off-load TDRSS for
 - Latency tolerant data delivery from LEO spacecraft
 - Communications outage restoration
- Commercial service providers reduce cost



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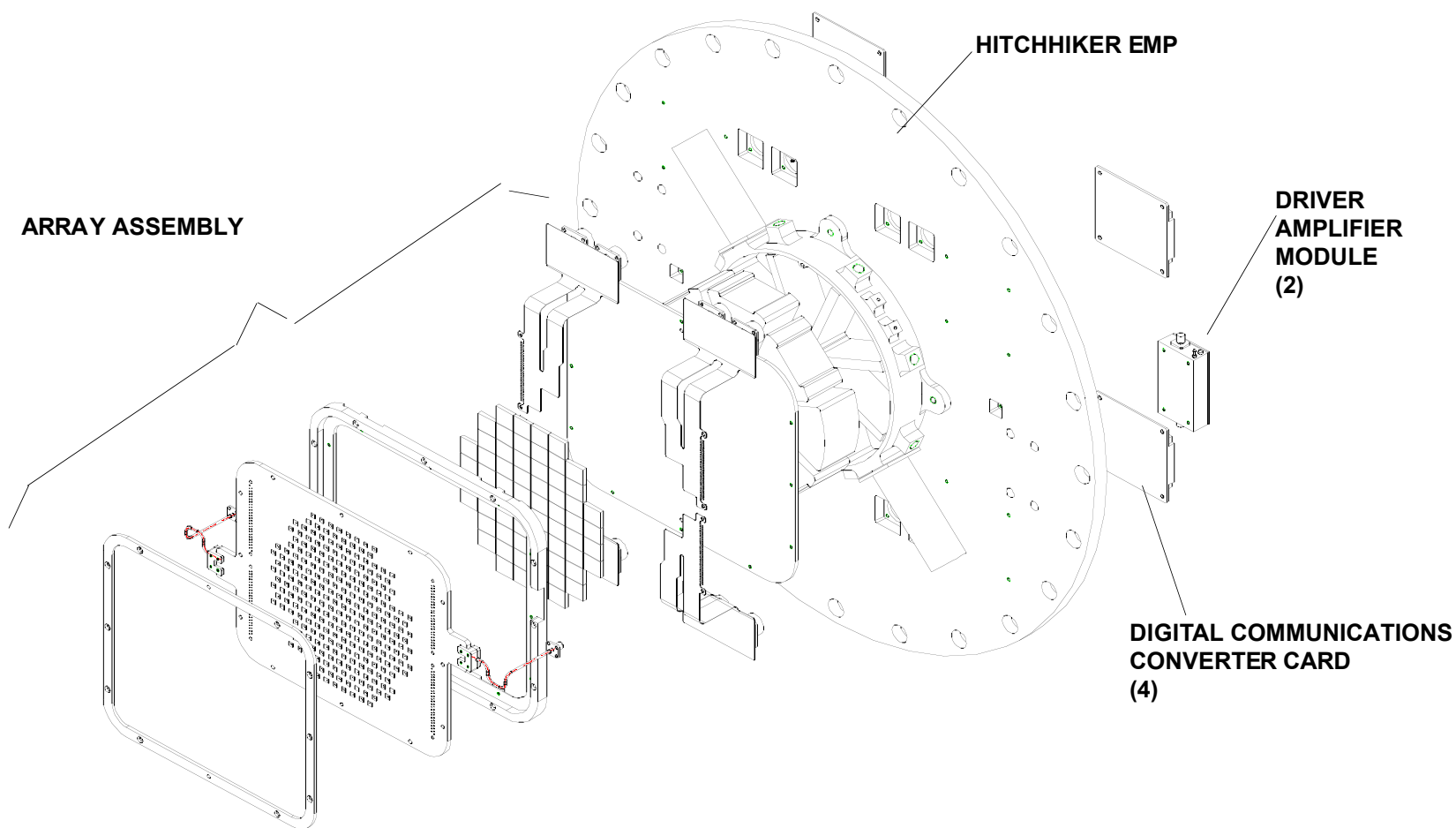
Direct Data Distribution Array





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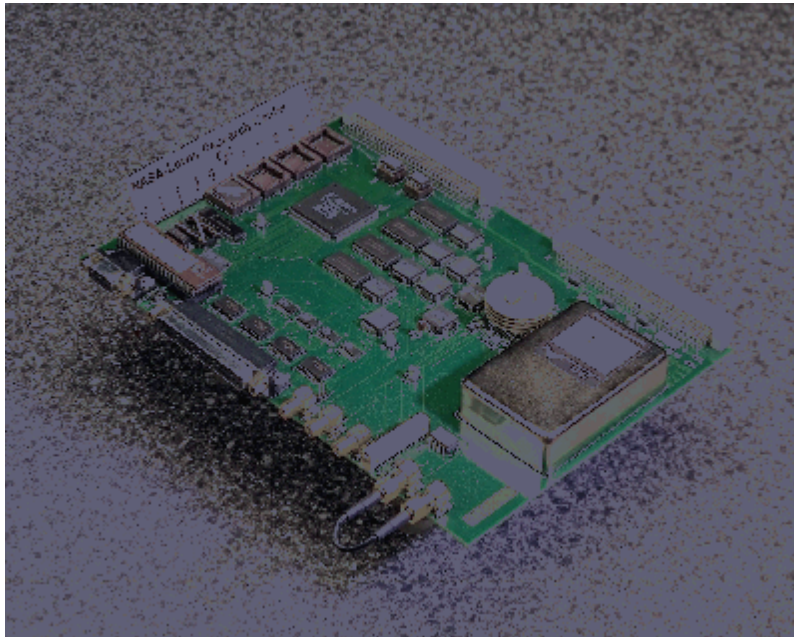
Array Assembly on Hitchhiker EMP





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Digital Encoder Modulator



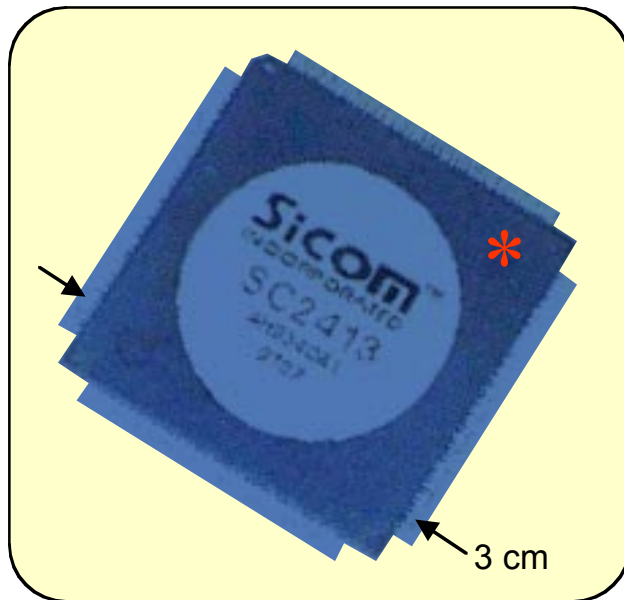
- 155-Mbps per channel
- 2-bps per Hz efficiency
- M-ary PSK, QAM, CPM
- Rate 5/6 pragmatic 4-D trellis coded modulation
- Concatenated RS (255,239) coding
- ~ 7.2 dB E_b/N_o for 10^{-12} BER
- 15 Watts DC (prototype)
- Commercial Partner for chipset

DEM Prototype



155 Mb/s Single Chip Modem

First commercially available 155 Mb/s modulator / demodulator chip set



* *Developed by SiCOM under SBIR program utilizing key LeRC-developed technology*

Features

- Selectable modulation formats - BPSK, QPSK, 8PSK and 16QAM
- Combined coding (Reed-Solomon (RS) and Viterbi) and modulation
- Programmable data rates from 1 Mb/s to 155 Mb/s

Impact

- Enables next generation wideband video and data services at OC-3 data rates
- Complete integration of modem functions reducing size, weight and power requirements
- Baseline for future flight qualified modem-on-a-chip implementations

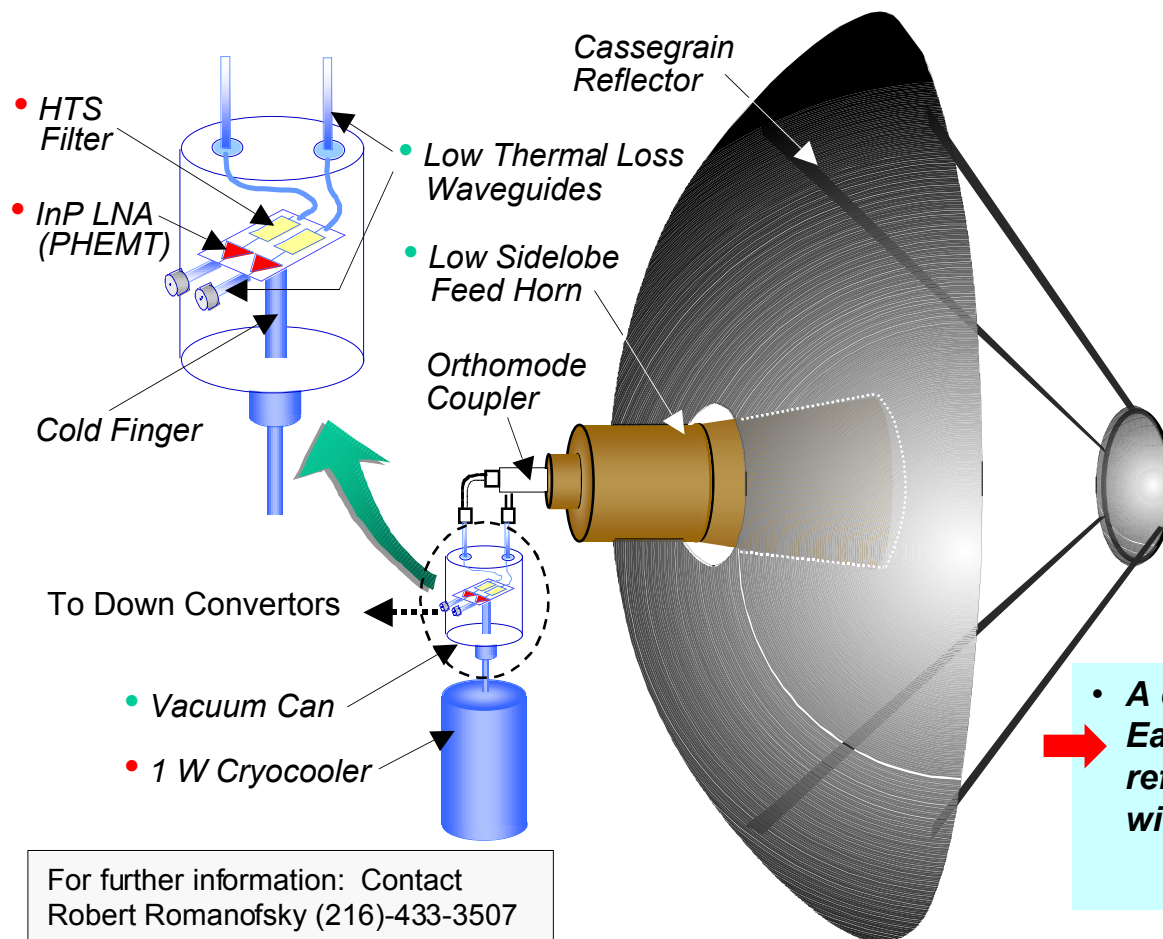
Future

- Next generation architecture is being incorporated in a radiation-hardened modulator ASIC to be completed in 3rd Q FY00



Cryoreceiver

- **Cryogenically cooled receiver will achieve a noise temperature of $\sim 150^\circ \text{K}$, a factor of ~ 4 reduction at 19 GHz, improving receiver performance by a factor of 4 (6db)**
- **6db is very highly significant to communication system designers - Enables a smaller space (or Earth) antenna... or increased data rate... or lower power....**



Features

- Exploits three key technologies:
 - Reliable cryocooler
 - HTS Filter
 - InP PHEMT low noise receiver (LNA) chip
- Other design features:
 - Vacuum can with low thermal loss waveguides
 - Low sidelobe feed horn

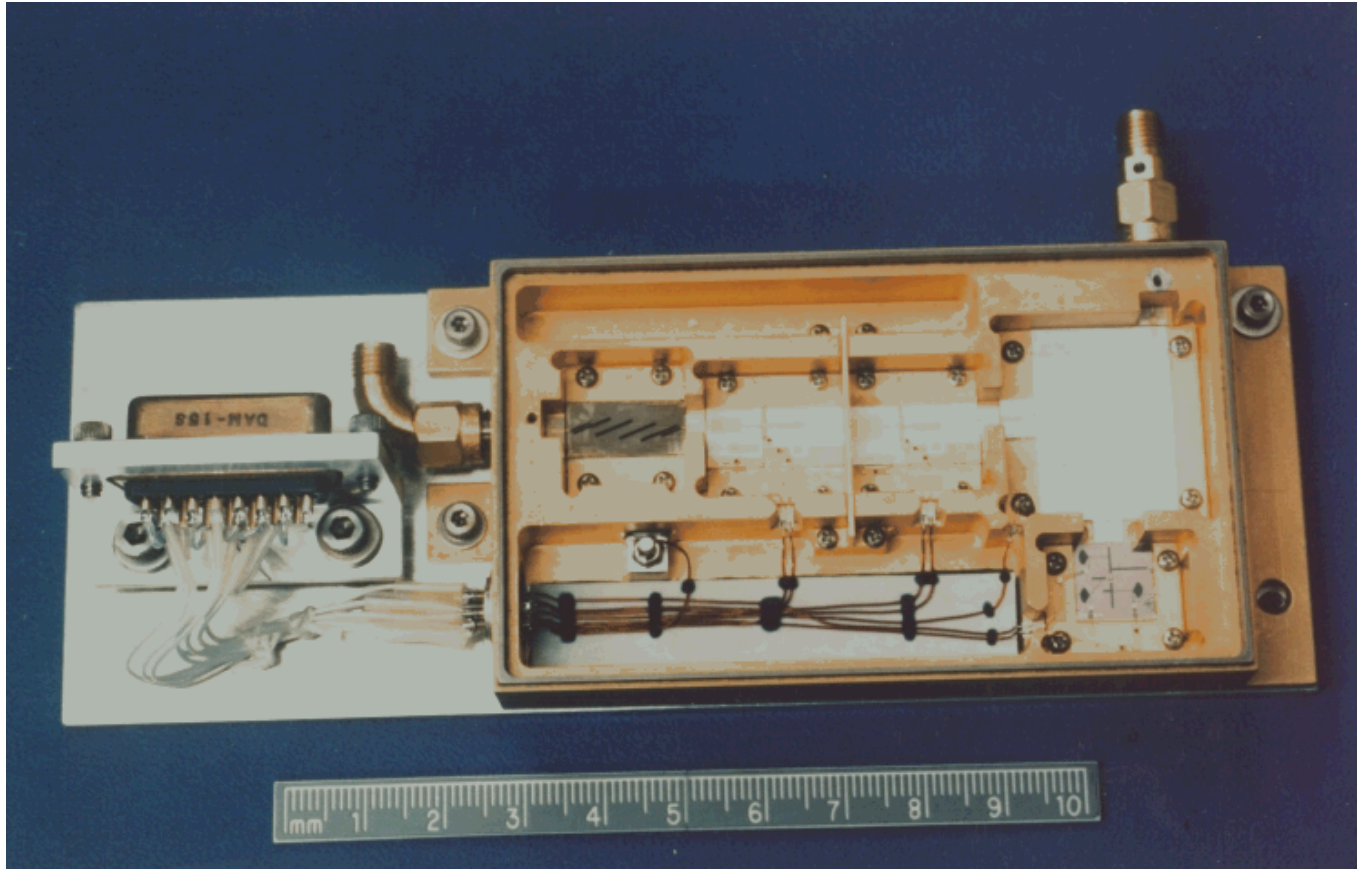
• **A cryoreceiver is baselined for the D³ Earth terminal - Allows smaller diameter reflector (0.9 m instead of 1.8 m) with wider beam width, simplifying tracking**

For further information: Contact
Robert Romanofsky (216)-433-3507



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X-Band Cryoreceiver



Space Qualified X-band Hybrid Superconductor/Semiconductor Receiver
[Cooperative development by NASA Lewis Research Center and the Jet Propulsion Laboratory for High Temperature Superconductor Space Experiment (HTSSE); delivered to NRL in 1994]



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Technology Insertion

4 Ka-Band TWTA for DSN

Dr. Vernon O. Heinen



Glenn Research Center

Ka-Band TWTA for DSN

Center: GRC
Funding Enterprise: Code M/SOMO
UPN-5: 315-90, 632-50

POC: V.Heinen
Phone: 216-433-3245
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Date: 3/25/1999
NTIDB Record #: N/A, 1881
Tech Prog Element #: 4

DESCRIPTION:

Current TRL: 4

Planned TRL: 6

- The objective of this effort is to develop a high efficiency 30 Watt 32 GHz TWTA for data return from deep space science missions to the upgraded DSN. This is a 3X increase in power and half the mass of the Ka-band TWTA flown on Cassini.
- Leveraging GRC TWT modeling capabilities to optimize design
- Effort will produce engineering model TWTA with options for flight qualified TWTA

JUSTIFICATION:

- Ka-band capabilities required on spacecraft for communications with upgraded DSN (Identified on JPL Ka-band Roadmap)
- TWTAs only validated technology to provide sufficient data return for many future missions
- Common RF amplifier will result in major cost savings for multiple future missions

RESOURCES (\$K):

	FY98	FY99	FY00	FY01	FY02	FY03
Guideline		400*	1550*	900*	300*	

*SOMO Augmentation Needed

MILESTONES:

- Q3FY99 Contract in place with manufacturer
- Q3FY01 Breadboard TWTA
- Q1FY02 Engineering Model TWTA

STATUS:

- Initial TWT design nearly complete
- GRC and JPL determining specifications and roles



Ka-Band TWTA for DSN

CUSTOMER(S):

- JSC SOMO - Supports SOMO role of supplying technology to missions
- JPL TMOD - Fills need for flight qualified Ka-Band amplifier in Ka-Band Roadmap
- Code S - Fills need for flight qualified Ka-band amplifier

MISSION RELEVANCE:

- TWTA will be available to broad range of deep space missions resulting in major cost savings
- Flight hardware available in <3yrs. No other technology capable of this power level in that time frame

MAPPING TO STRATEGIC ROADMAP:

Pillar 1: Reduce Cost of NASA Space Operations	1. Commercial Utilization	<input type="checkbox"/>	Pillar 2: Provide enabling data services to Enterprises	1. High Performance Comm	<input checked="" type="checkbox"/>
	2. Network Interoperability	<input type="checkbox"/>		2. Intelligent Syst & Autonomy	<input type="checkbox"/>
	3. System Automation	<input type="checkbox"/>		3. Innovative Info Syst	<input type="checkbox"/>
	4. Process Tools	<input type="checkbox"/>		4. Environm Characterization	<input type="checkbox"/>

INTER-RELATIONSHIPS:

- This effort is supported by significant leveraging of technology and technical capabilities previously developed under Code SM CETDP

IMPACT OF CANCELLATION or DELAY :

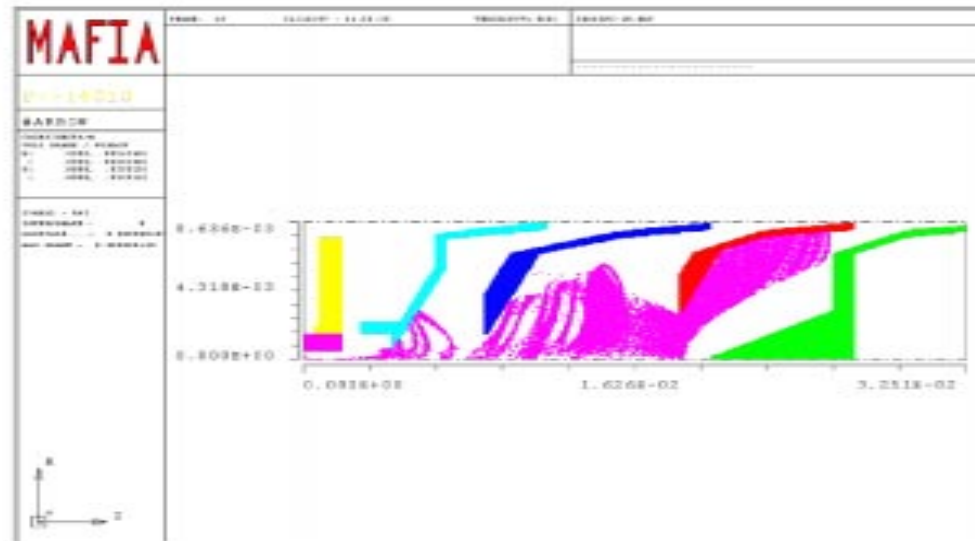
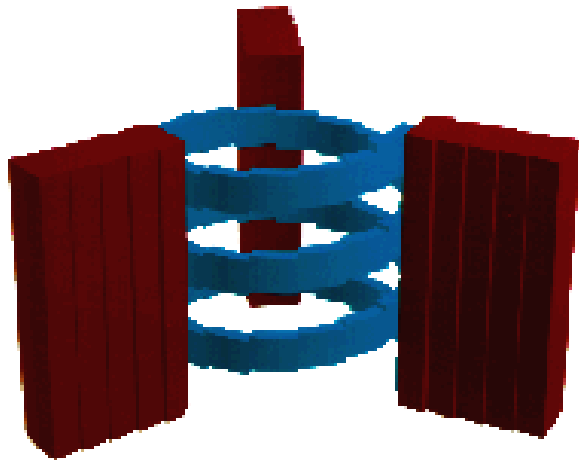
- No RF amplifier would be available to provide for high rate data return from planned missions for ~ 30 months from effort start



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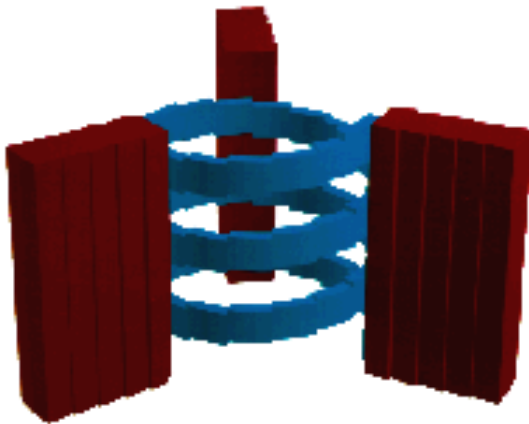
Computer Modeling of Microwave Devices

- GRC provides computer codes, design assistance and consultation to US industry, universities and other government agencies.
- Modeling eliminates need for pre-testing, shortens development time, reduces cost and improves performance.
- Very active collaboration with industry.
- Only NASA center with TWT technology development effort.





Computer Modeling of Circuit Impedance



PROBLEM:

- Direct measurement of impedance impossible
- Use dielectric rod to perturb fields
- Many approximations involved

HYPOTHESIS:

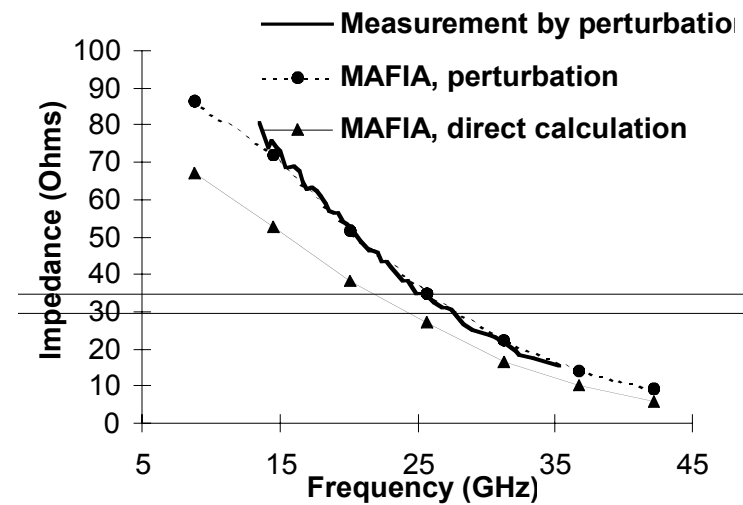
- Accurate helical computer model developed at GRC provides more accurate impedance than measurement

RESULTS:

- Model of experimental procedure agrees with measured values
- Direct computation of impedance differs significantly from measured values

IMPACT:

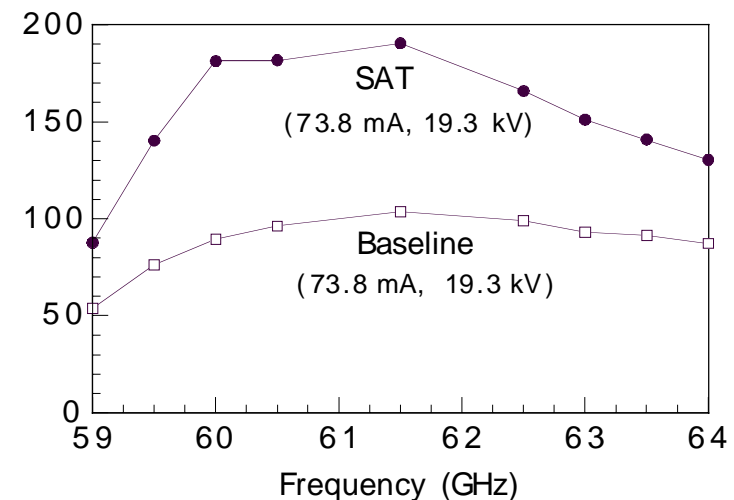
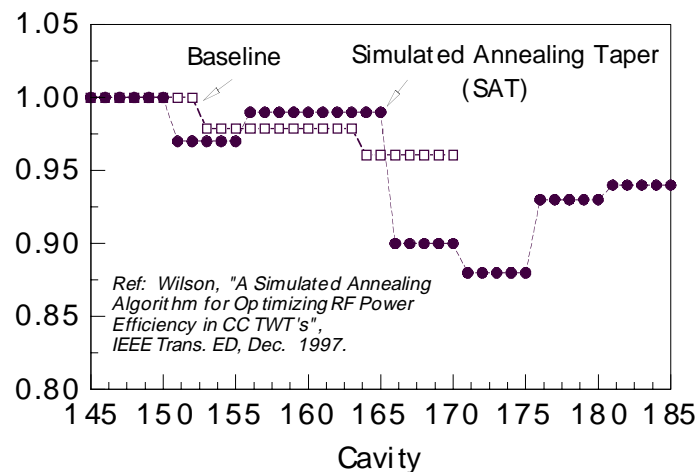
- More accurate impedance values
- Time-consuming and expensive measurements can be avoided





TWT Optimization

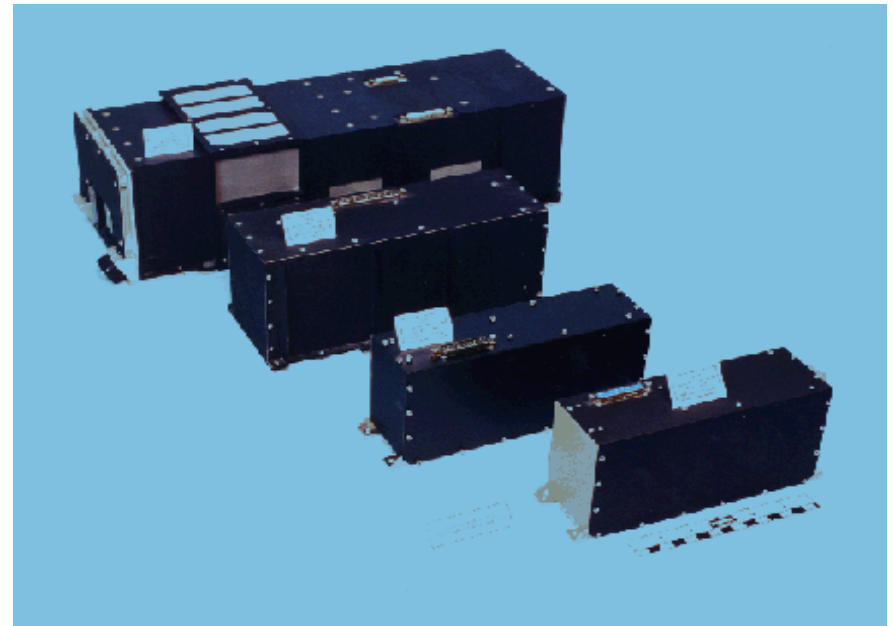
- Optimize TWT Circuits with Simulated Annealing
- RF Efficiency, Overall Efficiency, Bandwidth, Linearity
- Example for High Efficiency, Wide Bandwidth Intersatellite Communications V-Band TWT





TWT Power Supply

- 3 year, 50% cost sharing contract with Hughes Tele-communications and Space to improve performance of commercial Ku-band TWTA's
- GRC provided computer modeling assistance for TWT
 - GRC techniques adopted by Hughes
- Resulted in a 10% increase in TWT efficiency and 50% reduction in EPC mass
- 40% of 1997 sales attributed to the technology developed under this program
- Technology immediately adaptable to NASA missions





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Technology Insertion

5 Millimeter Wave Propagation

Dr. Roberto J. Acosta



Glenn Research Center

Millimeter Wave Propagation

Center: GRC
Funding Enterprise: Code M/SOMO
UPN-5: 315-90

POC: R. Acosta
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Date: 3/25/1999
NTIDB Record #: 9448
Tech Prog Element #: 5

DESCRIPTION:

Current TRL: 2

Planned TRL: 7

- Primary activity is to characterize the effects of rain (e.g., attenuation, depolarization) on millimeter-wave (e.g., Ka-, V-, and Q-band) communication links. Ongoing and future activity is to identify and measure all relevant parameters affecting the transmission of millimeter-wave propagation through earth-space atmosphere communications; these include, but may not be limited to, precipitation, aerosol, cloud, and gaseous absorption effects.
- A system of 10 propagation terminals will be deploy on tropical, sub-tropical and medium rain zones. The experiment terminals are up-grade (adding V and Q-bands LNAs) versions of the ACTS propagation terminals (Ka-band terminals). The Ka-,V and Q bands beacons are to be provided by the European Space Agency at no cost to NASA.
- The use of these observations to validate and extend propagation model to above Ka band frequencies.

JUSTIFICATION:

- Needed for communications system specification and cost-effective design for commercial communications, deep space network, TDRSS, and ISS that will required G bytes/sec on demand data rate transmissions.
- The research is an inherent government function and is consistent with IOA implementation.

RESOURCES (\$K):

	FY98	FY99	FY00	FY01	FY02	FY03
Guideline		165	185	210	365	365

MILESTONES:

- 4Q-FY99: Complete mission assessment, design of experiments and ground station modification design.
- 4Q-FY00: Complete ACTS propagation terminals up grades to V- and Q-bands.
- 4Q-FY01: Deploy ground stations and data collection commence.
- 4Q-FY02: 1st year data collection and data analysis of experimental results.
- 4Q-FY03: 2nd year data collection and data analysis of experimental results.

STATUS:

- Contract with Stanford Telecommunications to start April 1, 1999 to design the experiment (including data collection methodology) and identify and design all upgrades to the ACTS propagation terminals to operate at V and Q-bands.



Millimeter Wave Propagation

CUSTOMER(S):

- NASA GSFC TDRSS Ka-band communications.
- NASA JSC ISS Ka- and V-band communications.
- NASA GSFC Direct Data Ka- and V-band communication
- US Satcomm Industry and other Government Agencies

MISSION RELEVANCE:

- All NASA communications using commercial systems.
- Will require an understanding of research results for communication missions in FY04 and above.
- Deep space network requires these results for system margin design and cost effectiveness by FY02.
- TDRSS will utilize results to complete design of future TDRSS link and data distribution systems.

MAPPING TO STRATEGIC ROADMAP:

Pillar 1: Reduce Cost of	1. Commercial Utilization	<input checked="" type="checkbox"/>	Pillar 2: Provide enabling	1. High Performance Comm	<input checked="" type="checkbox"/>
NASA Space Operations	2. Network Interoperability	<input type="checkbox"/>	data services to Enterprises	2. Intelligent Syst & Autonomy	<input type="checkbox"/>
	3. System Automation	<input type="checkbox"/>		3. Innovative Info Syst	<input type="checkbox"/>
	4. Process Tools	<input type="checkbox"/>		4. Environm Characterization	<input checked="" type="checkbox"/>

INTER-RELATIONSHIPS:

- European Space Agency will provide beacon by FY02 at no cost to NASA.
- US propagation community will participate as principal investigators in the experiments.

IMPACT OF CANCELLATION or DELAY :

- Loss of understanding how satellite communications systems can overcome rain induced fades thus making them cost-effective and reliable .
- US Commercial industry will delay or miss the opportunity to obtain design data for making commercial systems cost-effective to NASA.



Customer References

JPL - Deep Space Networks

- Dr. William Imbriale-Senior System Engineer
- Dr. Anil Kantak- Senior System Engineer
- Dr. Nasser Golshan - Manager

NASA GSFC - TDRSS Program

- Mr. Anthony Comberiate-Project Manager (H,I,J)
- Mr. Marco Toral - Payload Technical Manager

NASA ISS - Project Communications

- Dr. Michael Jacox, System director

US Satellite Communication Industry

- Hughes Dr. Thomas Brackey, Director
 Dr. Len Goldin, Director
 Dr. Faramaz Davarian, Senior Engineer
- TRW Dr. Harvey Berger, Senior System Engineer
- Teledesic Mrs. Slata Koro, System Engineer
- Orbital Sciences Mr. Greg Giffen, System Engineer

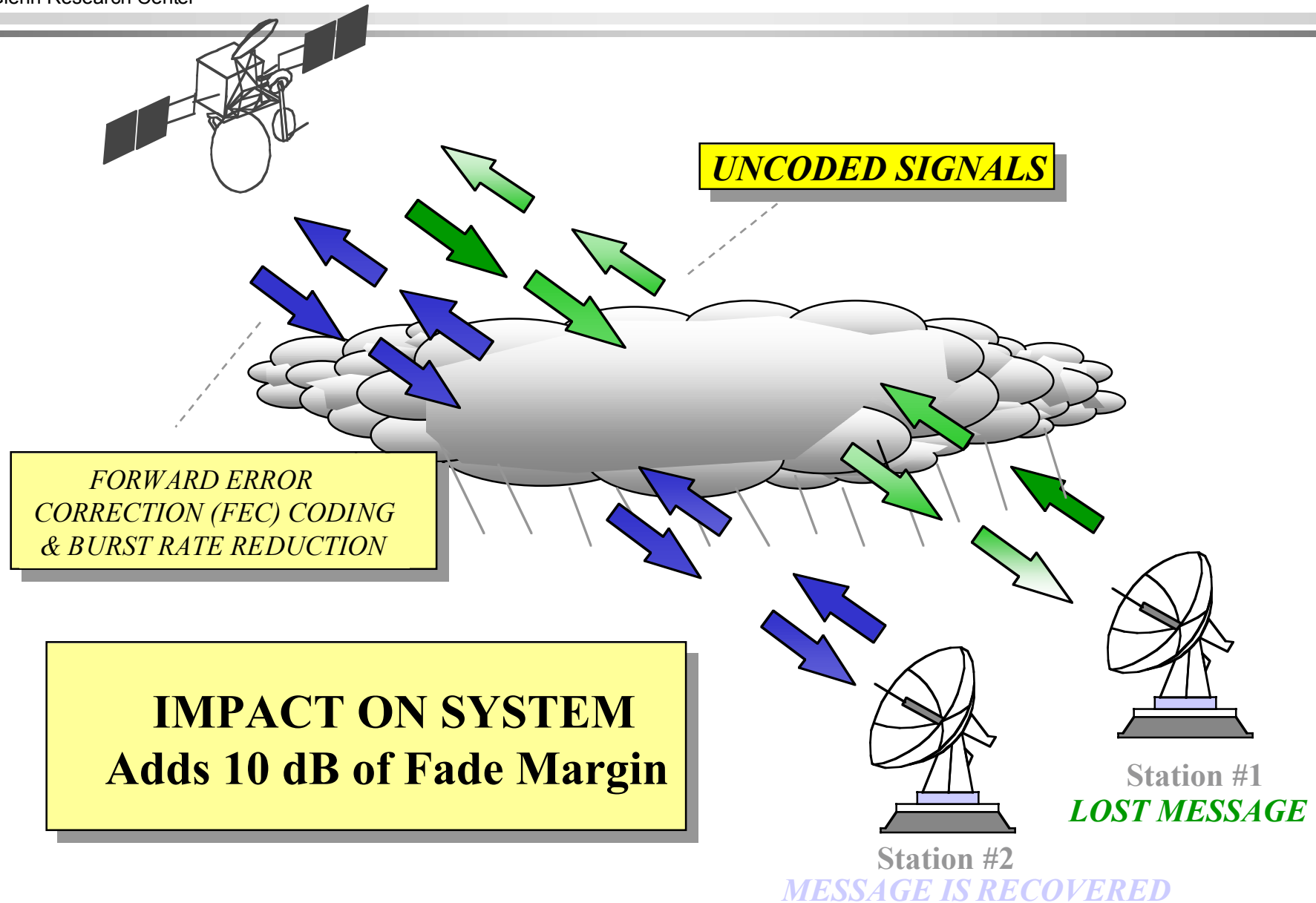
Government Agencies

- Department of Defence (GPS)
 Mrs. Allyson Yarbrough, Senior Engineer
 Dr. Richard Givens, Senior System Engineer



Glenn Research Center

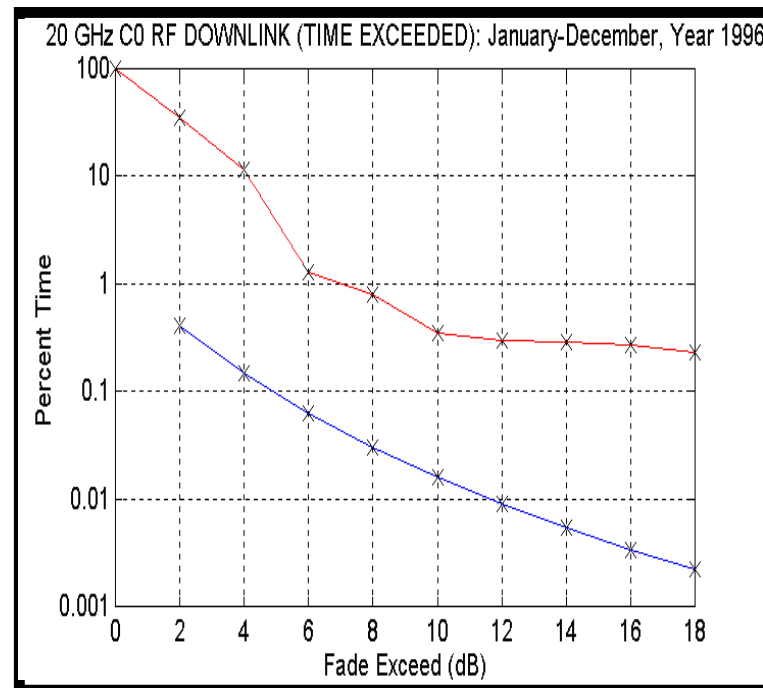
Rain Fade Compensation





Theory versus Experiment

Fade Availability for Cleveland -- 1996



GROUND STATION AND SPACECRAFT

DEGRADATION EFFECTS

- Multibeam antenna pointing errors
- Attitude control errors
- Measurement errors